TABLE OF CONTENTS

Page

TABLES

FIGURES

1.0 INTRODUCTION

The proposal by Cadman, Inc. includes a mining plan with four alternative methods of operation as described below. This technical report will evaluate the effects of the proposed gravel mining on the earth that underlies and surrounds the mining area. Potential impacts on the earth will be addressed. These include soils and geological hazards such as slope instability, soil erosion, and topographic alternation. The seismicity and liquefaction potential of the project area will be reviewed to assess the stability of reclaimed slopes during earthquakes. Mitigation measures are discussed for potential impacts identified for each alternative.

1.1 ALTERNATIVES

Development of a gravel extraction and processing operation has been proposed on land located east of North Bend, in unincorporated King County. Operations will include the excavation, washing, crushing, sorting, stockpiling, loading and hauling of sand and gravel. Four alternatives have been defined for the land, which are the basis for the analyses presented in this technical report:

- Alternative 1 – No Action.
- Alternative 2 – Two separate areas of land, referred to as the Edgewick, Lower Site, and the Grouse Ridge, Upper Site, will be developed for gravel extraction and processing. Construction of concrete and asphalt batch plants is planned at the Lower Site in later stages of site development. Extraction will initially occur in the Lower Site, with material hauled from the site via Exit 34 on I-90. Material excavated from the Upper Site will be moved to the Lower Site using a 36- to 42-inch-wide conveyor.
- Alternative 2 – Lower Site Option. Cadman, Inc., has included this option to decrease the footprint of the Lower Site's gravel operations to keep the operations at least one-quarter mile from the nearest residence. The amount of gravel to be removed will be reduced accordingly.
- Alternative 3 – Gravel extracted from the Edgewick (Lower) site will be transported from the site via Exit 34. After extraction has been completed in the Lower Site, the Upper Site would be developed, with material hauled out via SE Grouse Ridge Road to Exit 38 on I-90. Aggregate processing will take place on the Upper Site. Concrete and asphalt batch plants will be located at the Lower Site receiving material to be processed from the Upper Site via Exit 34. There will not be a conveyor line between the Lower and Upper sites.
- Alternative 3 – Lower Site Option. Cadman, Inc., has included this option to decrease the footprint of the Lower Site's gravel operations to keep the operations at least one-quarter mile from the nearest residence. The amount of gravel to be removed will be reduced accordingly.
- Alternative 4 – Extraction and aggregate processing will occur at the Upper Site, with processed materials hauled out via S.E. Grouse Ridge Road and Exit 38 on I-90. The Lower Site will not be developed and there will not be a conveyor line. There will not be onsite concrete and asphalt batch plants.

1.2 STUDY AREA

The project involves two separate sites east of North Bend, outside the city's Urban Growth Boundary, and a corridor for a conveyor between the sites. The Lower Site is about 115 acres located north of I-90 and east of 468th Avenue SE (Sections 18, 19 T23N R9E). The Upper Site is about 600 acres located north of I-90 on the Grouse Ridge plateau (Sections 28, 29 T23N R9E). The sites are approximately 1 mile apart, and the Upper Site is approximately 900 feet higher in elevation than the Lower Site.

1.2.1 Lower Site

Gravel has been extracted from the Lower Site periodically for many years. Over an approximately 5-year period, Cadman, Inc. proposes to extract gravel from 40 acres of the 115 acres, leaving the rest of the area as a buffer. An operations/processing center will be built at the base of the excavation, occupying 20.1 of the disturbed area. Earthen berms will be built up around the pit to restrict views and control noise. With the Lower Site Option, 33.5 acres of gravel would be extracted. A passive fresh water pond (164,200 ft^2) would be designed on the Lower Site to store pumped groundwater and stormwater.

Sand and gravel from the Upper Site will be washed or crushed, sorted and stockpiled at the operations/processing center for loading onto trucks and transportation off the site. Cadman, Inc. may construct buildings in which to mix concrete and/or asphalt. Roads, building floors, and maintenance areas will be paved.

1.2.2 Upper Site

The Upper Site on Grouse Ridge is a flat plateau comprising about 600 acres. Gravel will be extracted from approximately 260 acres over an estimated 25-year period of operation. Excavation will be in small segments, 50 acres or less at a time. As excavation is completed, each segment will be regraded and planted with native vegetation. About 360 acres of the Upper Site will be preserved as a buffer.

The only heavy equipment needed to extract gravel from the Upper Site is one rubber-wheeled front-end loader and one bulldozer. There may be times when additional equipment is used for special purposes.

1.2.3 Conveyor Corridor

Gravel will be transported down to the Lower Site on a 36-inch or 42-inch-wide conveyor belt. The conveyor will be on pedestal foundations that will average about four feet in height.

1.3 METHODOLOGY

The information used to assess the potential earth impacts and associated environmental consequences that may result from implementing the four stipulated alternatives are derived from five main sources:

- The applicant, Cadman, Inc.
- Review and evaluation of the Proposal as presented by Cadman, Inc. and all technical reports pertaining to the Proposal
- Public scoping procedures

- Research into published documents pertaining directly to Earth issues
- Environmental impact statements for other gravel mining operations in western Washington
- Conversations with selected regulatory agency personnel

2.0 AFFECTED ENVIRONMENT

2.1 TOPOGRAPHY

The Lower Site lies at the northwest base of Grouse Ridge at an approximate elevation of 600 feet. Is located on a natural flat terrace which extends west to the town of North Bend. To the south, I-90 separates the Lower Site from the South Fork of the Snoqualmie River at the edge of the terrace. Across the terrace to the north, the Middle Fork of the Snoqualmie River winds around and past Grouse Ridge.

Grouse Ridge is roughly L-shaped and rises to elevations ranging from 1,319 feet at the northern-most portion, to 1,650 feet in the southeast portion. The proposed Upper Site lies on the flat ridge atop of the southeast limb with steep slopes to the north and south. Grouse Ridge is situated between the Middle and South Forks of Snoqualmie River. Toward the northeast of the Upper Site are the Washington State Patrol Fire Training Academy and an existing road linked to I-90 to the south via Exit 38.

2.2 REGIONAL GEOLOGIC SETTING

The project site and the Puget Lowlands have been subject to several continental glaciation events during approximately the past 1 million years. Repeated advances and retreats of glaciers in British Columbia resulted in the formation of a mountain ice sheet. Continued growth of the ice sheet in British Columbia resulted in the southward advance of an ice lobe into the Puget Lowland (the Vashon Stade) about 19,000 years ago. In addition, glaciers in the Cascades extended west and merged with main lobe.

During the Vashon Stade, the Puget Glacier, a component of this most recent period of glaciation, extended over the Puget Sound Lowlands to as far south as Olympia and east to the Cascade foothills. It gouged out topographic depressions now filled by the Puget Sound, the Strait of Juan de Fuca, and lakes Washington and Sammamish to as far as Olympia and east to the Cascade foothills. The glacier remained at its maximum advance position long enough to deposit ice-contact and outwash sediments at the ice margin and into proglacial lakes, forming extensive morainal valley-fill deposits.

Upon withdrawal of the glacier, both the Middle Fork and South Fork of the Snoqualmie River eroded away much of the material that was transported and deposited by the glacier (moraine), leaving isolated plateaus such as Grouse Ridge. These melt-water streams and rivers beyond the active glacier ice left a broad swath of coarse soils (now referred to as glacial outwash soils) beneath Sallal Prairie west of and Lower than Grouse Ridge.

Some of the eroded materials were redeposited farther south as advance outwash soils. Much of it, however, was incorporated into the Vashon till – a non-sorted, non-layered sediment deposited directly by the glacial ice. Most of the Vashon till is very compact, because it was "plastered" onto the ground surface under the weight of several thousand feet of ice.

The geology in the vicinity of the project site is shown on Figure 1. The oldest rock exposed in the immediate area is a sequence of metamorphic sedimentary rock of possible Paleozoic Age. The metamorphic sequence is overlain by a series of volcanic flow rocks and sediments known as the Keechelus Andecites. During a period of regional uplift, which resulted in the present elevation of the Cascade peaks, the older formations named were intruded by granodiorite pluton known as the Snoqualmie batholith. The Snoqualmie granodiorite generally forms the core of the central Cascade Mountain Range and occurs extensively within the project area. All three types of bedrock are exposed along I-90 at roadway grade.

The valley of the South Fork of the Snoqualmie River was occupied by an alpine glacier during the Vashon Stade of the Fraser Glaciation. During this glacial advance, glaciofluvial and glaciolacustrine debris accumulated in the South Fork valley to thicknesses upwards of 800 to 900 feet. Eventual melting of the Vashon ice and subsequent incision of the south fork stream into the cross-valley terminal moraine have resulted in exposure along the existing river valley of all of the types of glacial sediments associated with the terminal moraine and the inter-valley lake impounded by the moraine. Incision of the river along the south valley wall also exposed spurs of bedrock, which projected, into the preglacial Snoqualmie Valley, producing several waterfalls along the existing river channel.

The Lower and Upper sites are principally located over these by alluvial deposits as shown on Figure 1. These surficial deposits range from moderately sorted gravel along rivers to poorly sorted gravelly sands deposited from small tributary fans. The Upper Site lies over recessional outwash soil deposits. These deposits consist of layered sand and gravel, moderately to well sorted, and well bedded silty sand to silty clay.

2.3 POTENTIAL SEISMIC ACTIVITY

2.3.1 Tectonic Setting

The tectonic setting of the Pacific Northwest for the last 60 million years has been dominated by collisions between tectonic plates. These plates of solid rock float on semi-plastic rock of the earth's interior and move in response to large, planet-scale currents in the mantle. Interactions between the plates result in the forces, which shape the earth's surface. The collision between the oceanic plate of the northern Pacific (i.e., the Juan de Fuca Plate) and the continental plate of North America resulted in formation of the Cascadia Subduction Zone (CSZ) and has given rise to the present morphology of Western Washington and is the principal cause of its current seismic activity.

The Pacific Northwest and adjacent continental margin have been divided into four major tectonic terrains reflecting the regional tectonic setting of the converging plates. These are the continental margin, the forearc, the volcanic arc, and the back-arc terrains (see Figure 2). The dynamic interaction between the two major converging plates (Juan de Fuca and the North American) defines the characteristic structure and location of these four terrains with respect to plate geometry and configuration (Atwater, 1995).

To view this figure, click on the link below.

Figure 1 Map of Local Geology

To view this figure, click on the link below.

Figure 2 Tectonic Setting of the Cascadia Subduction Zone

The continental margin includes the continental slope and the shelf offshore of Western Washington. The continental slope is an area of active continental accretion and the site of deposition of marine and continentally derived sediments. The western edge of the continental margin is marked by the suboceanic trace of the CSZ, which occurs 60 to 100 miles (96 to 160 kilometers [km]) west of the Washington coastline (see Figure 2).

The fore-arc is the area between the CSZ and volcanic arc of the Cascade Mountains. It is characterized by deformed and metamorphosed sedimentary and igneous rocks accreted to the continental plate during the plate convergence. Volcanic activity in the fore-arc occurred principally during the early stages of subduction (Kobayashi, 1983).

The Cascade volcanic arc was caused by the melting of continental margin rocks during the subduction of the Juan de Fuca Plate beneath the North American Plate, which has been occurring for the past 38 million years (Vance, 1982). The prominent volcanic cones of the Cascade Mountains were formed on top of the older landscape (McKee, 1972).

The back-arc terrain is located east of the Cascade Mountains and is underlain primarily by granitic and metamorphic rocks which, in the Columbia Plateau region, are overlain by thick layers of basalt flows. Because rocks underlying the Cascade volcanics and back-arc area are composed of the accreted terrains of past collisions, the region has complex bedrock geology.

2.3.2 Historical Seismicity

Earthquakes are the result of sudden releases of built-up stress within the tectonic plates that make up the earth's surface. The stresses accumulate because of friction between the plates as they attempt to move past one another. The movement can be between plates such as when one plate moves over another, as in subduction zones or within the plates themselves. Earthquakes in the Pacific Northwest can originate from four different types of sources: (1) interplate earthquakes on the CSZ, (2) intraplate earthquakes within the subducting Juan de Fuca plate as it sinks and breaks up below the North American plate, (3) shallow crustal earthquakes on faults within the North American plate, and (4) volcanic earthquakes such as those associated with the eruption of Mount St. Helens. These sources are depicted in Figure 3.

The relatively short duration of the historic record in the Pacific Northwest (approximately 150 years) is insufficient to indicate whether the CSZ has generated or is capable of generating a great earthquake of magnitude M8 or greater. This type of event apparently occurs every several hundred years and results in major earthquakes. Geologic studies during the last ten years have suggested that great earthquakes have occurred on the CSZ during the Holocene (Atwater, 1987a, b, 1992; Carver and Burke, 1987; Darienzo and Peterson, 1987, 1990; and Grant and McLaren, 1987). Geologic evidence for the most recent event (approximately 300 years before present [b.p.]) has been found at many coastal locations in Washington and Oregon. It is uncertain whether a single earthquake or several separate earthquakes closely spaced in time caused the geologic effects at these locations. There is general consensus that the CSZ has generated one or more earthquakes of M8 or larger in the past few thousand years (Atwater et. al., 1995).

To view this figure, click on the link below.

Figure 3 Cross Sections of Earthquake Hypocenters Beneath Western Washington

Rogers (1988) and Heaton and Hartzell (1986) suggest that a moment magnitude M=9.1 CSZ earthquake could occur that would rupture the entire 560-mile (900 km) length of the Juan de Fuca plate from Northern California to Vancouver Island. In the Final Safety Analysis Report (FSAR) for the Washington Public Power Supply System, Nuclear Project No. 3 (WPPSS, 1988), theoretical arguments are presented that the CSZ is segmented and that earthquakes would be confined within any of three segments of the CSZ. Because of its limited length (less than 190 miles [300 km]) each segment is only capable of generating earthquakes of M8 to 8.5. More recent studies indicate a tsunami occurred in Japan approximately 300 years ago that most likely was caused by an earthquake on the CSZ. Modeling of the tsunami supports the interpretation that this earthquake was at least M9. (Satake et al., 1996). Despite the geologic evidence for M8-9 earthquakes on the CSZ, there has been very little historical interplate seismicity on the CSZ below western Washington.

Intraplate seismic events occur at typical depths of between 30 to 33 miles (48 to 53 km) beneath Puget Sound. Based primarily on the historical seismicity of intraplate origin in western Washington and other subduction zones of the world, the intraplate zone is considered capable of generating earthquakes as large as M7.5. This source has generated two of the largest and most damaging historical seismic events to affect the Pacific Northwest: the 1949 Olympia earthquake of magnitude M7.1 and the 1965 M6.5 Seattle earthquake. Because intraplate earthquakes do not cause deformation at the ground surface that can be distinguished from other types of earthquakes, the typical frequency of these earthquakes cannot be readily assessed. However these types of earthquakes have historically caused the greatest amount of damage in the Puget Sound region.

Shallow crustal seismic events appear to occur more widespread geographically relative to the other sources of historical seismicity, and result from various structural sources in the shallow crust. These events often occur along mapped or postulated faults exposed at the earth's surface. Based primarily on historic and paleo seismicity, the Quaternary shallow crustal faults are considered capable of generating earthquakes greater than M6 and potentially as large as M7.0-M7.5, such as the 1872 North Cascade event which was estimated to be a M7.3.

The Seattle and Whidbey Island faults are the most potentially significant Quaternary faults west of the Cascades. These faults have not generated earthquakes greater than M6 historically, but the Seattle fault last ruptured the ground surface approximately 1100 years ago during an earthquake estimated to be M7.0-M7.5 (Bucknam et. al., 1992; Johnson and Potter, 1994). The Rattlesnake Mountain fault is located approximately 6.2 miles (10 km) west of Grouse Ridge. The largest instrumentally recorded shallow crustal earthquake in the Puget Sound area is the 1996 M5.3 Duvall earthquake which has not been associated with a recognized Quaternary fault. This fault is postulated to have been active during the Quaternary but evidence of displacement subsequent to the Vashon Stade has not been documented nor has there been historical seismicity associated with this fault.

Figure 4 shows the instrumentally recorded seismicity for the project region for the period of 1970-1993. The largest historical earthquake in the state of Washington was probably the 1872 event in the North Cascade Mountain Range. This event has been estimated to have a magnitude M7.3. Three events between M7.0 to M7.5 have occurred this century in the region: two beneath central Vancouver Island (1918, M7.0; 1946, M7.3), and one near Olympia, Washington (1949, M7.1). The most recent large earthquake occurred in 1965 between Seattle and Tacoma and was M6.5. Both the 1949 and 1965 earthquakes occurred at a depth of about 37 miles (60 km), whereas the 1872 event probably occurred at a shallow depth within the North American crustal plate.

2.4 SITE GEOLOGY

Presented in the section is a description of the site geology. The location of previous soil borings are shown on Figure 5. Geologic cross-sections depicting the subsurface conditions are shown on Figures 6 and 7.

2.4.1 Surface Soils

Although the proposed site areas are not included in the U.S. Soil Conservation Service soil survey for King County, surface soils were mapped for Weyerhaeuser in 1976 and are of the Klaus series. Soils of this series are somewhat excessively drained, gravelly loamy sand, formed under conifers in very gravelly glacial outwash.

2.4.2 Subsurface Soils

A Hydrogeologic Data Report prepared for Cadman, Inc. by Hart Crowser (1999a) identified a number of exploratory and water wells within and around the project area. The report identifies 50 holes that have been drilled and 81 water wells in the vicinity, most of which constitute water wells within the established aquifer system. Further investigation of the subsurface soils was conducted by Dames & Moore for the Water and Environmental Health technical report. The information presented in these reports was used to characterize the subsurface soils.

Soil reports completed for I-90 south of the project area reveal silty fine sands with cobbles. Typically, the area is overlain with outwash sediments (well to poorly sorted sand and gravel) which, in turn, is underlain by moraine sediments (unsorted granular deposits). Bedrock outcrops were encountered along the north banks of the South Fork and south of I-90 consisting predominantly of metamorphic, sedimentary, and igneous sequences.

2.4.2.1 Lower Site

Within the Lower Site boundaries, seven exploratory holes have been drilled, three of which are existing water monitoring wells (Figure 5). The subsurface investigations were drilled in two phases by Cadman, Inc., one in 1995 and one in 1998, and cover most of the property area. The borings were completed to 80 to 270 feet below ground surface (bgs) and are summarized below. An additional hole (GR99-1) was drilled to 130 feet bgs on May 17, 1999, to clarify the hydrogeology of the site, and was supervised by Dames & Moore. The boring log is contained in Appendix E, Water and Environmental Health Technical Report.

To view this figure, click on the link below.

Figure 4 Pacific Northwest Seismicity, 1970-1993

To view this figure, click on the link below.

Figure 5 Proposed Final Elevation of Gravel Operation

To view this figure, click on the link below.

Figure 6 Generalized Geologic Cross-Section Through Site Gravel Operation

To view this figure, click on the link below.

Figure 7 Generalized Geologic Cross-Section Through Upper Site Gravel Operation

The soils encountered were classified on a visual examination and sieve analysis conducted by Cadman, Inc. Soils encountered in the May 1999 boring (GR-99-1) were logged and classified by Dames & Moore in accordance with standards set by the American Society for Testing and Materials (ASTM) Unified Soil Classification System.

In addition to drilling, bulk sampling conducted in September 1998 by Cadman, Inc. to determine the contents of the deposit at the deepest depth possible and compare results from the 1995 drill logs (i.e., boulder contents). Approximately 6,000 cubic yards were excavated over a period of two days. One larger hole was dug 0 to 20 feet bgs to place the excavator at a lower level and provide truck access to it. The excavator then dug an additional trench from the 20-foot level to 40 feet below grade so that soil samples could be taken from the 00 -to 20-foot level and 20 to 40 feet for laboratory analysis. Photographs were also taken along with a log of the excavation.

The soils within the proposed Lower Site can be generally described and classified as grayish brown and gray, slightly silty sands and gravels, as shown in Figure 6. Cadman, Inc. has determined that economically marketable aggregates exist to depths of up to Elevation 563 feet (130 bgs) with the exception of sporadic silt zones encountered in borings GR-98-1, GR-98-7 and GR-99-1 (Table 1). The proposed depth of excavation of the Lower Site is down to Elevation 640 feet (53 feet bgs). The silt zones become more predominant at elevations below the planned mining depth.

TABLE 1
LOWER MINE SITE SAND AND GRAVEL DEPTHS

Boring/Well Identification	Ground Surface Elevation (feet above msl)	Estimated Market Value* (ft.)	Total Depth (ft.)
GR-95-12	678	0-100	100
GR-98-1	697	0-90	90
GR-98-3	680	0-75	100
GR-98-4	835	0-130	130
GR-98-6	694	0-120	130
GR-98-7	677	0-59, 73-80	80
GR-99-1	722	0-65, 79-130	130

* As defined by Cadman, Inc.

The shallow recessional material (coarse gravels and sands) in the central portion of the Lower Site contained wet or saturated intervals in two borings (GR-95-12 and GR-98-7). However, significant quantities of water indicative of an aquifer were not encountered, as evidenced by the logs for well GR-95-12 and borings GR-98-3, GR-98-6 and GR-98-7. Based on the presence of bedrock outcrops at the northeast corner of the Lower Site, and the shallow depth to bedrock determined by the geophysical survey of the area (Golder, 1995), shallow groundwater flow from the ridge adjacent to the east of the Lower Site may be controlled by the slope and elevation of the bedrock surface. Water levels in well GR-98-4 are approximately 100 feet above water levels in wells completed within the lower portion of the Lower Site and appear to represent this influence. The water levels in well GR-98-4 fluctuate in response to seasonal precipitation patterns similar to wells GR-98-1 and GR-99-1.

2.4.2.2 Upper Site

Twenty-one exploratory boreholes have been drilled within the Upper Site boundaries. Eleven of these boreholes were constructed in monitoring wells. Soils encountered during exploratory borings are generally brown to gray silty sands and sandy gravels.(Figure 5). The results of these subsurface investigations are summarized in Table 2. Generalized geologic cross-sections are presented in Figures 6, 7, 8, 9 and 10.

TABLE 2
UPPER MINE SITE SAND AND GRAVEL DEPTHS

Boring/Well Identification	Ground Surface Elevation (feet above msl)	Estimated Market Value* (ft.)	Total Depth (ft.)
GR-95-1	1,607	0-63	90
GR-95-2	1,641	0-120, 130-150, 180-200	200
GR-95-3	1,654	0-150, 160-170	180
GR-95-4	1,636	0-50, 60-63, 90-100	125
GR-95-5	1,635	0-30, 40-80	100
GR-95-6	1,655	0-50, 60-100	116
GR-95-7	1,635	0-150	170
GR-95-8	1,628	0-140	140
GR-95-9	1,607	0-90, 100-120	130
GR-95-10	1,646	0-270	270
GR-95-11	16,33	0-90, 180-220	220
GR-98-9	1,331	0-20	50
GR-00-01	1,631	NA	240
GR-00-02	1,640	NA	230
GR-00-04	1,636	NA	220
GR-00-05	1,630	NA	240
GR-00-06	1,635	NA	230
GR-00-07	1,645	NA	210
GR-00-06	1,613	NA	230
GR-00-09	1,614	NA	210`
GR-00-10	1,600	NA	210

* As defined by Cadman, Inc.
NA = Not Available

These soils are generally brown to gray silty sands and sandy gravels. Cadman, Inc.'s initial estimates show marketable soils extending to 270 feet bgs (see Table 2). As with the Lower Site, these soils extend to 270 feet bgs with the exception of occasional sandy silt and silt zones. These zones are found at various depths throughout the Upper Site and appear more extensive near the northwest and southeast margins of the proposed excavation area. These finer grained soils range in thickness from 10 feet thick in hole GR-95-9 up to 70 feet thick in hole GR-95-1.

To view this figure, click on the link below.

Figure 8 Generalized Cross-Section E-E' upper site

To view this figure, click on the link below.

Figure 9 Generalized Cross-Section F-F' upper site

To view this figure, click on the link below.

Figure 10 Ridge Conveyor and Maintenance Road Ground Line

The proposed depth of excavation of the 1,600 Upper Site is down to Elevation 1,535 feet (65 to 115 bgs). Currently, the flat plateau ranges from approximately Elevation 1,600 feet at the southeast end of the mine boundary, rising 50 feet to approximately Elevation 1,650 feet at the northwest end of the mine boundary. This excavation depth would pass through the sandy silt and silt zones predominantly at the northwest portion near borings GR-95-4 through GR-95-6.

The potential presence of groundwater beneath Grouse Ridge was evaluated by reviewing logs and water level data for the monitoring wells and borings installed on the ridge. The water level data for the two monitoring wells (GR-95-2 and GR-95-3) show that groundwater occurs beneath the central portion of the ridge throughout the year at Elevations 1,510 to 1,540 feet. Water in these wells appears to be perched on layers of silt or silty sand. The perched zones are a result of the combination of deposition and erosion, which formed the upper portions of the ridge and left primarily coarse sediments with lenses of fine-grained sediments where ponding or flooding may have occurred. The localized lenses of fine-grained material impede downward groundwater movement and allow perched conditions. These zones occur at Elevations 1,500 to 1,510 feet or about 100 feet below the ground surface. The water levels fluctuate in response to seasonal precipitation patterns.

Cadman, Inc. drilled two subsurface exploration boreholes in close proximity to this proposed route in 1998. Investigations in GR-98-2 revealed deposits of sands and gravels at least 25 feet thick on the lower half of the route, underlain by clay. These deposits increase somewhat in thickness with an increase in elevation. GR-98-10 was drilled to a depth of 70 feet and shows the sand and gravel deposits to be at least 50 feet thick. Results of these holes are summarized below in Table 3.

TABLE 3
EXISTING SUBSURFACE DATA ALONG PROPOSED CONVEYOR BELT ALIGNMENT

Hole Number	Route Proximity	Elevation (ft)	Sand/Gravel	Clay	Total Depth (ft.)
GR-98-2	Lower half	937	0-25	25-70	70
GR-98-5	Upper half	1,061	0-40	40-70	70

To assess the presence of groundwater in areas beneath the ridge where monitoring wells were not installed, boring logs were reviewed to identify depth intervals that were noted on the logs to be either wet or saturated. The presence of wet or saturated conditions was considered evidence of groundwater. This review indicates that at some locations there are up to six potential water-bearing zones in the upper 270 feet of the deposits beneath the ridge. The wet and saturated intervals appear to be limited in extent in the upper 100 feet of the sand and gravel and then become somewhat more widespread at depths between 100 and 200 feet bgs. It should be noted that the borings and wells on the Upper Site were installed in September 1995 during what is typically the driest time of year and when groundwater levels are lowest. The fall of 1995 also corresponds with the period during which water levels in wells GR-95-2 and GR-95-3 were the lowest during the period of record. Given the time of year that the borings drilled on the ridge, the potential exists that intervals described as moist or dry may seasonally contain groundwater.

The groundwater in these upland aquifers occurs under perched conditions. The perched nature of the groundwater in these wells is exhibited by the absence of wet or saturated conditions in sandy material encountered in boring GR-95-3 at lower elevations than the saturation measured in the monitoring well. In addition, in many of the borings where wet or saturated zones were encountered, these saturated zones were underlain by dry or moist zones.

2.5 GEOLOGICALLY HAZARDOUS AREAS

Geologically hazardous areas are lands, which are susceptible to landslides, erosion, or seismic movement due to underlying soils and geology. The areas surrounding the proposed project limits are considered geologically hazardous areas due to steep slopes, and areas where erosion and landslides have happened in the past.

Steep slopes bound the Upper Site to the north and south. Steep slopes are defined in King County's Sensitive Ordinance as any slope greater than 40% (22 degrees). These represent a geological hazard with respect to landslides. Most landslide hazard areas in the Grouse Ridge vicinity involve relatively loose soil on slopes underlain by denser and typically less permeable till.

Specific identification and mapping of these geologically hazardous areas are shown in the North Bend Gravel Operation Exit 38/Homestead Valley Alternative Technical Assessment, prepared for Cadman, Inc. and the Weyerhaeuser Company by Hart Crowser in 1999b.

2.5.1 Erosion Hazards

Erosion is a natural process of the wearing away of land surfaces by water, wind and ice. While erosion and sedimentation are natural processes at work in the landscape, they are frequently accelerated by land use modifications and urban development.

The susceptibility of soil to surface erosion depends on its physical and chemical characteristics, slope, vegetative cover, the intensity of rainfall, and runoff velocity. Eroded material is moved by wind or surface water runoff and deposited elsewhere as sediment. The negative effects of increased sedimentation are most pronounced where erosion of soils is connected to the surface drainage network. Through sedimentation, soil erosion can result in degradation of surface water quality and/or aquatic habitats.

The proposed site areas are not included in the DNR Forest Practice Resource map and King County Erosion Hazard Areas map depicting areas of potential erosion hazard. However, Hart Crowser (1999b) states that the slopes on the south and, consequently, the north, are covered with unstable soils that are prone to erosion. The DNR Forest Practice Resource map also indicates that soil adjacent to the Snoqualmie River is highly erodible. This is to be expected given the restricted channel and high energy of the river.

2.5.2 Landslide and Steep Slopes Hazard Areas

The identification of areas susceptible to landslides is necessary for informed land use planning and to support land development regulations, which reduce the risk of property damage, personal injury, and environmental degradation.

Landslide hazard in the project area lie principally on the southern flank of Grouse Ridge. Landslide flow paths can directly impact the South Fork of the Snoqualmie River. These events are documented in the

South Fork Snoqualmie River Watershed Analysis (1995). In this analysis, figures show that in 1984, above Twin Falls (RM_{10}), 2,367 tons per year was deposited in the river as a result of soil creep and landslides. Landslide hazard areas are defined by alternate or co-existing landscape conditions, which are based on well-established geo-technical determinations of slope stability and considerable experience and research in the Puget Sound area.

The stability of slopes in landslide hazard areas is highly dependent on the water content of the underlying soils. Water readily percolates through sand and gravel, but ponds above less permeable silt, clay and till layers, thus saturating the overlying deposits. Where a less permeable layer (silt or clay) intersects a slope, water often seeps from the layers above. This combination of sedimentary deposits, steep topography, and local groundwater flow results in a high potential for landslides. An event that increases groundwater levels and flow, such as a rain storm or discharge of surface water above a slope, can saturate sediments near the surface and cause failure of a slope that is stable under drier conditions. Likewise, erosion along a stream channel or excavation at the toe of a slope can steepen a slope or expose deposits which may become water saturated, increasing the potential for landslides on a previously stable slope.

Most landslide hazard areas in the Grouse Ridge vicinity involve relatively loose soil on slopes underlain by denser and typically less permeable till. All areas with surface soils underlain with relatively impermeable soils on slopes of 15% or greater and with drainage from topographically higher areas, and all areas with steep slopes greater than 40% (except consolidated rock), can be classified as potential landslide hazard areas (Hart Crowser, 1999b). Most slopes on the south and north sides of Grouse Ridge exceed this 40% criteria and, as such, are subject to naturally occurring periodic landslides.

Within the proposed mine sites, the slopes are regulated by the Federal Mine Safety and Health Act (MSHA) of 1977, which applies to all mining activities. It is not designed to be an environmental statute and does not impose broad permitting requirements on mine operators. Nevertheless, within the MSA's broad parameters are requirements for the mine operator to obtain pre-mining approvals and allow MSHA to review certain mining plans prior to the start of mining.

2.5.3 Seismic Hazards

Damage from earthquakes is caused primarily by ground shaking. The severity of ground shaking is dependent upon the following: the distance of a site from the earthquake epicenter, the magnitude and duration of the earthquake, the nature and thickness of surface and subsurface geologic materials and subsurface geologic structures. Other direct causes of earthquake damage are surface faulting and sudden ground elevation changes such as subsidence and uplift. Earthquakes may also trigger landslides, soil compaction, and liquefaction of water-saturated deposits.

The project area is in Seismic Zone 3 in the 1997 Uniform Building Code (UBC), as is all of Western Washington. Per the UBC zonation, Zone 1 indicates the region of lowest seismic risk and Zone 4 indicates the region of highest seismic risk. Therefore, the project area is in a region of relatively high seismic risk.

Seismic hazard areas can be defined as areas subject to severe risk of earthquake damage as a result of seismically induced settlement or soil liquefaction. Loose, water-saturated soils tend to experience the most severe ground shaking during an earthquake. When shaken by an earthquake, such soils lose their ability to support a load; some soils will actually flow like a fluid (liquefaction). Loss of soil strength can result in failure of the ground surface (settlement, surface cracking, and landslides) and damage to structures. Much of the floor of the upper Snoqualmie Valley has been identified as a seismic hazard area in the Sensitive Areas King County Map Folio (1990).

The potential seismic hazards at the project site include earthquake-induced landslides of cut slopes, movement of the conveyor system and damage to asphalt and concrete facilities from strong ground shaking. However, available studies of seismic hazards have designated soils within the proposed project boundaries as having a low susceptibility to liquefaction. Liquefaction takes place when loosely packed, water-logged sediments lose their strength in response to strong ground shaking. Land use planning strategies and engineering measures can be used to reduce the health and safety risk due to seismic hazards in hillside areas where landslides and rock fall are possible. Structures built in accordance with UBC and current engineering standards are designed to perform well with minimal damage from ground shaking.

One of the most effective methods to protect the operation of the proposed mine and associated facilities from seismic hazards is the development of an earthquake disaster response plan. This plan would assign specific responsibilities to Cadman, Inc. officials should a significant earthquake occur and would outline the relationship between Cadman, Inc.'s disaster preparedness plan and jurisdictional disaster response plans. The plan should also identify particularly hazardous buildings so damage response teams know where the most likely locations for structural failure and casualties.

Cadman, Inc. has a policy of issuing a disaster plan based on the philosophy that “in the event of a fire, windstorm or other natural disaster resulting in possible or threatened risk to life or company property, it is the Company’s belief that the risk of injury to employees and loss to Company property can be reduced significantly with a well organized and well publicized emergency procedure plan and organization."

2.6 SOIL METAL CONCENTRATIONS

Human exposure can occur via intake of water or airborne dust with elevated metals concentrations. Dames & Moore took soil samples from a recent soil boring (GR-99-1) and conducted an analysis for total metals concentrations. The concentrations of detected metals in the soils are comparable to the natural background concentrations of metals in surface soils found statewide and regionally. Based on the standards of the Model Toxics Control Act, the levels found are acceptable and do not pose a risk to human health or the environment. Results of the analysis are summarized in Table 4.

Metals, including arsenic, occur naturally in rocks and soil. Environmental exposure to metals can occur through weathering of rocks and erosion, and subsequent deposition of metals in surface water bodies, with subsequent intake of the metal by animals and plants. At this time, there are very few groundwater supplies in the United States that exceed the current arsenic standards. However, there are wells in some parts of the southwest and other localized areas around the country that do exceed this standard.

TABLE 4
SUMMARY OF TOTAL METALS WITHIN BOREHOLE GR99-1

GR99-1 at 75 feet	Analyte				
	Arsenic	Cadmium	Chromium	Lead	Mercury
Sample Result (mg/kg)	7.89	ND	14.1	5.56	ND
Statewide/Puget Sound 90th Percentile Values (mg/kg)	7	1	42/48	17/24	0.07

Note: ND = Not Detected

3.0 ENVIRONMENTAL CONSEQUENCES

3.1 CONSTRUCTION SOILS AND GEOLOGY IMPACTS

Construction impacts on the soils and geology are evaluated in this section for four project alternatives defined in Section 1.0. Construction impacts on the soils and geology include activities that occur as a direct result of operation construction and completion. These include roadway and conveyor belt construction and use together with reclamation.

3.1.1 Alternative 1 – No Action

There are no construction soils and geology impacts associated with the No Action Alternative.

3.1.2 Alternative 2 –Proposal

There are a number of earth activities in Alternative 2 that are considered construction impacts to the soils and geology in the study area. The indirect impacts in Alternative 2 include:

- Construction and improvement of roadways
- Construction of a conveyor system with an access road
- Construction of a passive fresh water pond
- Construction of earthen berms
- Clearing and preservation of topsoil and woody debris
- Reclamation activities

3.1.2.1 Soils

During the first phases of mining, the Lower Site will be extracted over about five years. During this time, access roads to and within the pit will have to be improved and constructed. A road to Exit 34 already exists, and was primarily constructed during previous mining of the area.

After an estimated 5 years of extraction, operations at the Lower Site will cease and an operations/processing center will be built on the excavated floor. Roads, building floors, and maintenance areas will be paved. Earthen berms will be constructed in the early phase around the mine boundary to restrict views and control noise. One earthen berm will be located to the north and one to the south.

The final conveyor and maintenance road route from the lower pit area up the west slope of Grouse Ridge will be laid out, in a straight line up to the Upper mine site. This alignment stretches approximately 5,300 feet and rises 800 feet in elevation. The conveyor could use a 36- or 42-inch wide belt and average about 4 to 5 feet above the grade. It will include a cover to blend in with the tree canopy, and to prevent rainwater and debris from mixing with the aggregates. Tree branches will be permitted to grow over the conveyor. The conveyor maintenance road will be paved to minimize dust and erosion.

As it crosses the north lip of the ridge, the conveyor can most likely be trenched to eliminate visibility from the Middle Fork Valley, I-90 and residences. If this plan is deemed infeasible during final design an alternative will be employed to screen views.

Conventional conveyor haulage systems have an optimum-working grade of 16 to 17 degrees (28 to 30% grade). Preliminary calculations indicate that in general the route is less than this limit and, as such, would not require extensive regrading of the natural ground line. Figure 3.10 shows an approximately profile of the alignment. The construction width is yet to be determined of this corridor but wide enough to accommodate the conveyor, access road and a water-pipe system. The access road will be paved and additional trees will be planted as necessary to provide for visual screening of the conveyor.

Exit 38 is proposed to be used as part of the haulage road. The Transportation Technical Report discusses this in more detail. However, this road would have to be improved and upgraded. The upper elevations of this road could prove to be too steep for truck access as it presently exists and would have to be constructed in such a way to satisfy the conditions.

The USGS map of the Snoqualmie Pass (1986), indicates that this area consists of recessional outwash deposits. It could be reasonable to assume that the soils would be similar to that of the ridge and comprise sands and gravels.

3.1.2.2 Reclamation Slopes

Pursuant to a DNR-approved reclamation plan, the mine sites would be progressively reclaimed over an approximately 25-year mine life, including revegetation with trees. Reclamation sideslopes would be established during excavation of the sand and gravel deposit. No side- slope back filling is required to achieve reclamation standards. Construction of this conveyor system and access road could have a moderate slope stability impact on the ridge. Road construction on steep slopes may increase the susceptibility for landslides. Roads can change natural drainage patterns and cause detrimental changes in soil drainage.

Reclamation of finished sand and gravel mine boundaries would include construction of slopes at a maximum 2 Horizontal (H):1Vertical (V) (27 degrees) that would slope back into the mine. A 2H:1V slope angle is substantially flatter than the natural angle of repose for in-place sand and gravel (e.g., 1.5H:1V, or 33 degrees), and would assure that cut banks were not oversteepened and would not cave or slough to create a low to moderate impact.

Reclamation of finished conveyor corridor is proposed to involve removing the conveyor, equipment and support structures. The access road asphalt will be broken up and removed for recycling or dispersed in place after which, the route will be graded, fertilized and planted to minimize erosion.

After vegetation growth, the long-term impacts to the soils and geology are expected to be low.

3.1.2.3 Topsoil Management

Because soil is essential to successful reclamation, it would not be sold as a by-product of mining. Soil to be used during mine reclamation would be separately stockpiled. The stockpiles would be placed in adjacent areas that would not require disturbance for the life of any particular mining subphase. Stockpiles would be positioned to assist in shielding the excavation from view and to help mitigate noise impacts, but would not become permanent features such that they could not be removed and used for sub-phase reclamation.

Soil stockpiles would be shaped and seeded with perennial grass seed mixtures suggested by the Natural Resources Conservation Service (NRCS), the Department of Natural Resources, and the Washington Department of Game, to reduce loss of fines into stormwater until such time as vegetation was reestablished. Shallow stormwater retention ditches would be excavated around soil stockpile perimeters, as needed, then drained to a retention pond. While retention of significant volumes of stormwater is not anticipated due to the porous, permeable nature of site soils, retained water would be pumped back into a settling pond located within the plant site and then directed into the wash water recirculation system.

3.1.2.4 Alternative 2 – Lower Site Option

Impacts associated with the Lower Site Option would be less because of the smaller area of impact (6.5 acres less).

3.1.3 Alternative 3 – Lower and Upper Sites (Exit 34 and Exit 38)

Construction impacts associated with Alternative 3 will be less than Alternative 2 due to the absence of the conveyor belt and maintenance road alignment on the western edge of Grouse Ridge. This would not involve any road building and construction associated with this route. The same impacts will apply to this alternative, however with the material haulage road from the Lower Site using Exit 34 and from the Upper Site using Exit 38.

3.1.3.1 Alternative 3 – Lower Site Option

Impacts associated with Alternative with the Lower Site Option would be moderate because of the smaller area of impact (6.5 acres less).

3.1.4 Alternative 4 – Upper Site Only (Exit 38)

Construction impacts associated with Alternative 4 will be less than Alternative 2 and 3 due to a smaller area of impact. The same impact will apply to this alternative as previously mentioned in Alternative 2 and 3, with the exception of disturbing 33.5 acres associated with the Lower Site.

3.1.4.1 Cumulative Impacts

Alternatives 2, 3 and 4 would contribute to an overall depletion in the regional sand and gravel resource.

3.2 OPERATION SOILS AND GEOLOGY IMPACTS

The operation impacts on the soils and geology upon the four project alternatives, as defined in Section 1.0 are evaluated in this section and include any activities associated with operation of the Lower and Upper sites. These activities include excavation that could significantly impact the topography and mineral resources, or that could increase erosion or decrease slope stability.

3.2.1 Alternative 1 – No Action

There are no soils and geology impacts associated with the No Action Alternative.

3.2.2 Alternative 2 – Proposal

This alternative involves onsite excavation of soils from both the Lower and Upper Sites, in phases with aggregate processing initially being conducted off site prior to the development of operation facilities on the Lower Site.

Excavation will begin at the Lower Site first, within a 40-acre area. It is during this phase that gravel will be hauled off site for processing. Excavation will begin at the west boundary of the operations area and proceed to the east.

A primary crusher will be installed for use on a temporary basis. It will be used until the Upper Site is opened and excavated to a point where space for this function can be provided. Final excavation in this area will establish parameters and lay-out of the future operations area including final side slopes incorporating grading and landscaping in accordance to regulations administered by the DNR as stipulated in the Surface Mine Reclamation Act RCW78.44 (as amended by SB5502 adopted in 1993).

Initial excavation will begin in the northwest portion of the Upper Site, near the conveyor. Excavation will be set back approximately 100 feet from the western lip of the ridge. As the deposit is mined downward and progresses in an easterly direction, all activity will be lowered within the excavated bowl shape. As the excavation progresses, overburden will be removed from new deposit areas in one-year increments prior to extraction.

The conveyor system and access road could increase the likelihood of offsite impacts such as landslides, increased streambank erosion, and increased sediment delivery. This is primarily due to the fact that improperly designed roads could concentrate runoff flows changing natural drainage patterns.

Six Bonneville Power Administration (BPA) utility towers exist along the southern boundary of the Upper Site pit with one other tower within the actual footprint itself, BPA indicated during recent discussions that they require a horizontal buffer of 50 feet, measured from the point of contact between the leg and ground surface. Any slope after the buffer is required to have a 2H:1V gradient. It is presumed that this will in effect be the limit of the reclaimed slopes and that working slopes shall be located further away. It is proposed that mining would extend as a 2H:1V slope gradient from the 50-foot setback and that reclaimed slopes will have a gradient of 3H:1V to 4H:1V with the use of a deposit waste overburden and fines. Conceptual plans submitted by Cadman, Inc. dated March 17, 2000, do not show detailed topography. If this horizontal buffer is maintained, there will be no impact.

Phased site development would require sequential removal of vegetation and soil stripping from areas to be mined. This activity would increase the susceptibility to erosion of both unvegetated stockpiled soil and denuded or excavated ground until soil replacement and plant stabilization is accomplished. Gravel will be removed from both sites over a long period of time, approximately 25 years. Excavation will be in small segments, 50 acres or less at a time. As excavation is completed, each segment will be regraded and planted with native vegetation. Because surface soil on both proposed sites is composed of a coarse gravelly and sandy nature, soil stripping would be a relatively simple and clean process. Some of the fines within the soils would be lost to stormwater flow. However, due to the absence of significant surface water drainage associated with the site, and the porous nature of site soils, sediment-laden stormwater is not expected to be generated in significant volumes, to have a significant onsite travel distance and hence, create only low level erosional impacts. Open mining segments will be internally drained and contained as excavation progresses. Presently, no benching is proposed for the working slopes.

3.2.2.1 Lower Site Option for Alternative 2

The impacts to soils and geology will be similar to, but slightly less, than those discussed, with a decrease of disturbed area equal to 6.5 acres.

3.2.3 Alternative 3 – Lower and Upper Sites (Exit 34 and Exit 38)

The impacts to soils and geology for Alternative 3 will be similar to those listed in Alternative 2.

3.2.3.1 Alternative 3 – Lower Site Option

The impacts to soils and geology will be similar to, but slightly less, than those discussed, with a decrease of disturbed area equal to 6.5 acres.

3.2.4 Alternative 4 – Upper Site Only (Exit 34)

The impact to soils and geology would be reduced overall without the development of the Lower Site.

3.3 SUMMARY OF MITIGATION MEASURES

3.3.1 Alternative 1 – No Action

No mitigation measures are being proposed.

3.3.2 Alternatives 2, 3 and 4

All impacts of the alternatives will be mitigated through standard design and construction practices common to the local industry. Specific mitigation measures will include the following:

- All excavation and reclamation will be in accordance with federal statutes of the Mine Safety and Health Act and the Surface Mining Act, requiring reclaimed slopes for sand and gravel to be 3H:1V to 2H:1V, working slopes at angle of repose. The proponent is proposing 3H:1V to 4H:1V final reclaimed slopes to insure standard forest management practices can be used in the final land use.

- Topsoil would be redistributed on finished sand and gravel mine slopes as soon as possible after restoration of topography within each mining subphase in order to minimize erosion and nutrient loss. Through advance soil stockpile placement planning, soil would be moved only once, to the extent possible. Heavy equipment would be used to reapply reclamation topsoil, but would not re-enter the area following soil application.

Fines from the wash water and fines settling basin and decomposed wood waste generated from site vegetation-clearing activities would be combined with stockpiled, to manufacture subsoil. This subsoil would be distributed over the surface of the finished mine floor, followed by distribution of the stockpiled organic-rich topsoil.

Once final mine reclamation is complete, stockpiled topsoil would be placed on the cut slopes to serve as a stable rooting medium for trees. Upon completion, topsoil would be placed randomly over the quarry floor to a sufficient thickness and extent to assure the establishment of a forest.

3.4 SIGNIFICANT UNAVOIDABLE ADVERSE IMPACTS

3.4.1 Alternative 1 – No Action

No soils and geology impacts would be associated with this No Action Alternative.

3.4.2 Alternatives 2 and 3

The natural topography will be altered, essentially leaving two bowl-shaped areas where the mines were. Consequently, the natural sand and gravel resource of the area will be diminished, covering an approximate area of 293.5 to 300 acres (this range is due to the Lower Site Option). As a result, there will be slope stability and erosion effects, where before there were effectively none, from the introduced reclaimed slopes cut into the topography.

3.4.3 Alternative 4 – Upper Site Only (Exit 38)

The natural topography will be altered, essentially leaving two bowl-shaped areas where the mines were. Consequently, the natural sand and gravel resource of the area will be diminished, covering an approximate area of 260 acres. As a result, there will be slope stability and erosion effects, where before there were effectively none, from the introduced reclaimed slopes cut into the topography.

4.0 SOURCES OF INFORMATION

Atwater, B.F., et. al. Summary of Coastal Geologic Evidence for Past Earthquakes at the Cascadia Subduction Zone; Earthquake Spectra, v.11, no. 1, 1995.

Atwater, B.F., 1987a. A Periodic Holocene Recurrence of Widespread, Probably Coseismic Subsidence in Southwestern Washington; EOS, v. 68, no. 44.

Atwater, B.F., 1987b. Evidence For Great Holocene Earthquakes Along the Outer Coast of Washington State; Science, v.236, no. 4804, pp. 942-944.

Best Management Practices for Reclaiming Surface Mines in Washington and Oregon by K.K. Norman, P.J. Wampler, A.H. Throop, E. Frank Schnitzer, and J.M. Roloff for the Washington Division of Geology and Earth Resources, Open File Report 96-2, revised edition, December 1997.

Bucknam, R.C., et. al. 1992 Abrupt Uplift Within the Past 1700 Years at Southern Puget Sound, Washington. Science 258:1611-1614.

Cadman, Inc. North Bend Gravel Operation, North Bend, WA Technical Information Report #A98MO242, CH2M Hill, October 1998.

Cadman, Inc. 1999. Sample Disaster and Emergency Organization Plan, 1999.

Cadman, Inc. “North Bend Gravel Proposal” video.

Cascade Gateway Foundation to King County Transportation Division, William Hoffman, November 3, 1998.

Dames & Moore Report No. 1; Geological Investigation, Interstate Highway No. 90, Edgewick Road to Olallie Creek, King County, WA for the State of Washington Department of Highways. June 26, 1967; Dames & Moore Archive No. 4342-046-05 SA1

Dames & Moore Report No. 2; Geological Investigation, Interstate Highway No. 90, Edgewick Road to Olallie Creek, King County, WA for the State of Washington Department of Highways. August 30, 1967; Dames and Moore Archive No. 4342-046-05 SA1

Dames & Moore Report No. 3; Geological Investigation, Interstate Highway No. 90, Edgewick Road to Olallie Creek, King County, WA for the State of Washington Department of Highways. December 19, 1967; Dames and Moore Archive No. 4342-046-05 SA1

Darienzo, M.E., and C.D. Peterson, 1990. Episodic Tectonic Subsidence Recorded in late Holocene Salt Marshes, Northern Oregon Central Cascadia Margin; Tectonics, v.9, pp. 1-22.

Department of Natural Resources, Washington, Forest Practice Resource Map.

Federal Surface Mine Reclamation Act (RCW 78.44) 1977.

Final Environmental Impact Statement, Washington State Patrol Fire Service Training Academy near North Bend, Washington, King County Department of Planning and Community Development, Building and Land Development Division, November 1981.

Frizzell, Jr., V.A., R.W. Tabor, D.B. Booth, K.M. Ort, and R.B. Waitt, Jr., 1984. Preliminary geologic map of the Snoqualmie Pass 1:100,000 Quadrangle, Washington. (Open File Map 84-693, 1:100,000), U.S. Geological Survey, Denver, CO.

Geomatrix Consultants, 1990. Seismotectonic evaluation, Walla Walla Section of the Columbia Plateau Geomorphic Province. Prepared for U.S. Department of Interior, Bureau of Reclamation. Grouse Ridge Query Workshop Minutes, April 27, 1998.

Grant, W.C., and D.D. McLaren, 1987. Evidence for Holocene Subduction Earthquakes Along the Northern Oregon Coast [abs.]; EOS, v. 68, no. 44, p. 1239.

Grouse Ridge Mine, Snoqualmie City Council Meeting Notes, July 27, 1998.

Hart Crowser, 1999a. Hydrologic Data Report, North Bend Gravel Operation, prepared for Cadman, Inc. J-4950-02, February 24.

Hart Crowser, 1999b. North Bend Gravel Operation Exit 38/Homestead Valley Alternative Technical Assessment, prepared for Cadman, Inc. and the Weyerhaeuser Company, J-7095.

Heaton, T.H., and S.H. Hartzell, 1986. Earthquake Potential Associated With the Cascadia Subduction Zone, In Hays, W.W., and Gori, P.L. (eds), Proceedings of Conference XXXIII, "Earthquake Hazards in the Puget Sound, Washington Area," U.S. Geological Survey Open File Report 86-253, pp. 52-57.

Infiltration Testing Results, Construction Aggregates Limited – Grouse Ridge Site, completed by Hart Crowser for Cadman, Inc. September 9, 1998.

Johnson, S.Y., Potter, C.J., and Armentrout, J.M., 1994. Origin and Evolution of the Seattle Basin and Seattle Fault: Geology. V. 22, p. 71-74 insert.

Kobayashi, K., 1983. Forearc Mechanisms, Physics and Tectonics, Proceedings of the 1981 IAUECEI Symposium, Tokyo; Terra Scientific Publications, Tokyo.

Manson, 1999. Telephone correspondence with Connie Manson, Washington Department of Natural Resources, May 26, 1999.

Mine Safety and Health Act, 1977. Chapter 3.3.

McKee, B., 1972. Cascadia, McGraw-Hill, New York, NY, 392 p.

Moses, 1999. Telephone correspondence with Lynn Moses, Gravel and Pits Manager, Washington Department of Transportation.

Model Toxics Cleanup Act, 1991. Methods A and B, Chapter 173-340, WAC.

National Well Owners Association.

Natural Background Soils Metals Concentrations in Washington State by Charles San Juan, Toxics Cleanup Program, Olympia, WA 98504-7600, Publication No. 94-115, October 1994.

Newport, 1999. Telephone correspondence with Grant Newport, Manager of Coal and Mineral Resources, Weyerhaeuser, June 10, June 14, 1999.

Norman, 1999. Telephone correspondence with David K. Norman, Chief Reclamation Geologist, Washington Department of Natural Resources, June 2, 1999.

Rogers, G.C., 1988. An Assessment of the Megathrust Earthquake Potential of the Cascadia Subduction Zone; Can.J.Earth Sci., v. 25, pp. 844-852.

Satake, K; et. al., 1996. Time and Size of a Giant Earthquake in Cascadia Inferred From Japanese Tsunami Records of January 1700; nature, v. 379,pp. 246-249.

Sensitive Areas Map Folio, King County, WA, December 1990.

Shaver, 1999. Telephone correspondence with Mary Anne Shaver, Sand and Gravel Resources, Washington Department of Natural Resources, May 26, 1999.

Shearer, 1999. Telephone correspondence and personal communications with Rod Sheerer, Cadman, Inc.

Smith, 1999. Personal communications with Brad Smith, Operations Superintendent, Cadman, Inc. Black Diamond Gravel Operations, May 14, 1999.

South Fork Snoqualmie River Watershed Analysis, February 1995, pp. 1-22.

Summary of the Grouse Ridge Memorandum of Understanding, April 29, 1998.

Thompson, Gordon, 1999. Personnel communications with King County Department of Development and Environmental Services (DDES).

Uniform Building Code, Structural Engineering Design Provisions, Vol. 2, 1997.

USGS Chester Morse Lake Quadrangle, Washington, King County, 7.5 Minute Series (Topographic).

Vance, JA, 1982. Cenozoic Stratigraphy and Tectonics of the Washington Cascades [abs.], Geological Society of America, Abstracts with Programs, v. 14, no. 4.

Washington State Highway Commission District No. 1 Reclamation Plan, Pit Site PS – A – 456, King County. October 8, 1971.

Wescot Company Homestead Valley Pit, King County Grading Permit No. 1374-53 (including Dames & Moore Soils Report), June 7, 1974.

WoodRiver Comments, April 28, 1998.